UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

POTENTIAL FLOOD AND DEBRIS HAZARDS, AT WILLOW BEACH, LAKE MEAD NATIONAL RECREATION AREA, ARIZONA

Administrative Report for release only to
U.S. National Park Service

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Carson City, Nevada

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CONTENTS

ILLUSTRATIONS

CONVERSION FACTORS

For those readers who may prefer to use metric units rather than U.S. Customary units, the conversion factors for terms in this report are listed below:

U.S. Customary unit	Metric unit	Multiplication factor to convert from Customary to metric quantity
Inches (in)	Millimeter (mm)	25.40
Feet (ft)	Meters (m)	.3048
Miles (mi)	Kilometers (km)	1.609
Square miles (mi^2)	Square Kilometers (km^2)	2.590
Cubic feet per second (ft^3/s)	Liters per second (L/s)	28.32

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ABSTRACT

The diked channel on Willow Beach Wash will not convey floods of 25-year or greater recurrence interval. Serious hazards from manmade objects being moved and widespread deposition of debris from these floods should be expected. The most vulnerable reach is from section D to downstream of section B (pl. 1).

The Jumbo Wash campgrounds may be inundated by flows of 25-year or greater recurrence interval because the dikes are low or nonexistent in places. Debris hazards include dangers from manmade objects moving and extensive debris deposition, and debris deposition at the wash terminus during floods of all sizes.

Of the three washes, Access Road Wash is probably the least hazardous in terms of overall potential flood and debris hazards. The Ranger headquarters and the employee residences may be in hazardous locations for the 100-year or greater recurrence interval flood.

INTRODUCTION

In 1977 the Water Resources Division of the Western Regional Office, National Park Service, requested and funded a flood hazard potential study by the Geological Survey of the Willow Beach site in the Lake Mead Recreation Area.

Willow Beach is a developed recreation site on the Arizona side of Lake Mohave (fig. 1). The site includes camping and picnicking facilities for motor travelers and permanent facilities such as docks, a restaurant, a motel, and trailer berths and hookups for semi-permanent residents operated by a National Park Service licensed concessionaire. All the facilities are in or adjacent to normally dry stream channels; the access road is also in the bed of a normally dry stream channel.

The above described recreation complex referred to in this study as Willow Beach includes the lower reaches of Willow Beach, Jumbo, and Access Road Washes as well as the lakefront between these washes (fig. 2). The names Willow Beach Wash and Access Road Wash were assigned for this report, as they both are unnamed on all maps. The study includes the appraisal of flood hazards in and along the channels of these three principal washes.

Delineation of flood hazards should demonstrate the extent and severity of hazards to occupied or potentially occupied areas. Such information may provide a basis for making safety-related modifications at the recreation site or, as a minimum, determine relative flood-hazard risks associated with present operations.

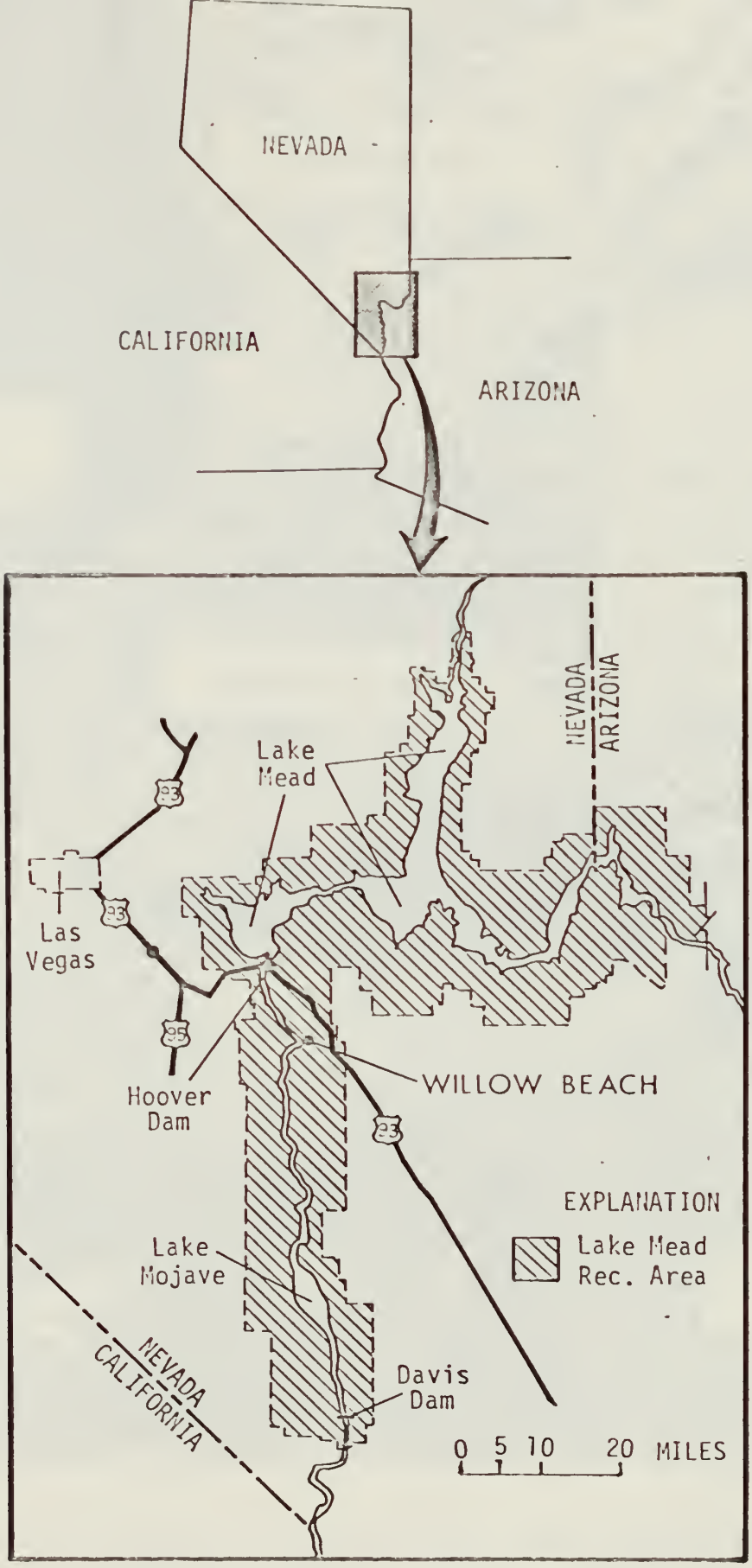

Figure 1.--Location of Willow Beach.

Figure 2.--A vertical view of Willow Beach and tributary washes, February 22, 1954.

HYDROLOGIC SETTING

The study area is within Lake Mead National Recreation Area in Arizona on the east side of Lake Mohave. Lake surface levels normally fluctuate from 15 to 20 feet per year in meeting power development and irrigation requirements. The climate at the study site is decidedly arid--the mean annual precipitation is about 4 inches and air temperatures greater than 120°F have been recorded.

All streams in the vicinity of Willow Beach are dry except during or immediately after heavy precipitation. If the streams flow at all in any one year, the warm season from June to October is the most likely time. Convective thunderstorm cells that are isolated and small in area, or are imbedded in large-scale tropical storm systems, can cause extensive short-term flooding.

The magnitudes of flows have not been systematically monitored in any one of the three washes. A flood peak of 2,810 cubic feet per second (ft^3/s) on September 8, 1975, was measured by the slope-area method in the lower reach of Jumbo Wash. This flow caused considerable damage and was the highest known during the past 20-25 years. A 1965 flood in Willow Beach Wash damaged areas near the marina but the flow magnitude is not known. All three streams flowed during an unusually wet September and October 1976, and Jumbo Wash flowed in August 1977. None of the 1976 or 1977 flows were large enough to cause damage.

The time between intense rainfall and subsequent flooding at the mouths of the three washes is extremely short; approximately one hour or less for most severe events, except Jumbo Wash which may experience

flooding several hours after intense rainfall because of its larger drainage area. Warning time is very short and to be effective may have to be based on anticipated storms. It may be feasible to incorporate visual and radar observations with the ongoing stream water level warning system.

POTENTIAL FLOOD AND DEBRIS HAZARDS

As considered in this study, potential flood and debris hazards are defined by several characteristics of streamflow: flow velocities, flow depths, areal extent of flood inundation, and the amount and character of debris likely to be mobilized by the flows. Generally, the higher the flow velocities and flow depths, the greater are the flow hazards. For example, anyone caught in even 2-feet-deep rapidly flowing water would run a high risk of being moved, upended, and drowned. If flow velocities and depths become large enough, automobiles and mobile homes will be transported by floodflows and may become upended or destroyed; they are not a safe haven in extreme flood periods. Similarly, floods that inundate large areas, pose greater hazards than floods of more limited areal extent. In addition, debris moving with the water increases the hazards. Among the chief hazards caused by debris loads are the obstruction and modification of floodflows, abrasion and impact by the moving debris, and burial by debris deposition. Death by drowning is the principal hazard to people. Injury or death by impact or abrasion by high velocity debris and possible burial by debris are additional hazards. Hazards to property are chiefly those due to impact, abrasion, and burial by rapidly moving water and sediment.

Flood and debris hazards are not separate entities, but they are discussed separately in this report for simplicity and ease of presentation.

Potential Flood Hazards

To appraise the flood potential at a site, the magnitude and frequency of flooding and the stream-channel capacity must be determined. Flow magnitude is expressed as discharge, or flow volume per unit time. The term "recurrence interval" is defined as the average interval of time within which a flood of a given magnitude is equaled or exceeded. A flood with a recurrence interval of 25 years is the flood that is equaled or exceeded once in 25 years, on the long-term average. The concept implies no regularity in the time of recurrence of a given flood magnitude. Flood characteristics may also be expressed in terms of probability. The probability of occurrence of a flood exceeding the 25-year flood in any given year is one in 25, or 0.04.

The flood-frequency discharges of the three principal washes at the study site were estimated (table 1) using the results of regression studies made for streams in desert areas of southeast California (Waananen and Crippen, 1977). Regression equations relate measurable basin characteristics such as drainage area, mean annual precipitation, altitude and slope to the flood discharges of various recurrence intervals. Although the drainage area of Jumbo Wash is greater than the 25 mi^2 limit suggested in the California report, the equations are judged applicable. The results agree reasonably well with regression studies for northwest Arizona (R. H. Roeske, U.S. Geological Survey, oral commun., 1977). Each discharge shown has a standard error of estimate of 50 to 100 percent.

Table 1.--Peak discharge estimates

Stream name	Drainage area (square miles)	Peak discharge, in cubic feet per second for indicated recurrence interval, in years				
		10	25	50	100	Q extreme
Willow Beach Wash	4.40	330	1,000	1,900	3,100	27,000
Access Road Wash	5.61	370	1,200	2,300	3,700	31,000
Jumbo Wash	36.4	1,000	3,900	8,100	14,000	99,000

A relation based on the maximum observed floods throughout the United States (Matthai, 1969, p. B6), was used to estimate a practical upper limit of extreme flood severity. The equation is:

$$Q_{extreme} = 11{,}000\ A^{0.61}$$

where Q extreme = discharge in cubic feet per second and A = drainage area in square miles. Larger floods are not impossible. On September 14, 1974, washes tributary to Eldorado Canyon experienced flows of 44 to 89 percent of the Q extreme (Glancy and Harmsen, 1975). The mouth of Eldorado Canyon is about 10 air miles southwest of Willow Beach.

The channel-flow capacities for the three washes were measured as part of the field instrument surveys made in March and April 1977. Channel-flow capacity is related to cross-sectional area, channel slope, and degree of flow resistance offered by the channel bed and banks. Bank and channel bed configurations of the study-area washes have been significantly altered by recreation area development. In the natural state, the channel bed for each of the three washes was relatively flat in the lateral direction. For flows of most sizes, the hard-rock canyon walls served as channel banks. The lateral boundaries of the relatively obscure low-flow channels moved within the confines of the canyon walls in response to such factors as discharge magnitude and debris loads. Recreation site development in Willow Beach and Jumbo Washes stabilized these low-flow channels by confining flows in each wash between one rock wall and an earthfill dike. At many locations, the fill in back of the dike is as high as the dike itself. Within confines of this arrangement, flow velocities and depths will be larger than predevelopment velocities and depths for the same discharge magnitudes. Inundation areas after diking obviously will be less than before diking for corresponding flows.

Jumbo Wash has been forced against the left (south) canyon wall by a dike beginning from the farthest upstream development near the water supply tank to its mouth. The developed area, consisting of camping and picnicking facilities, is between the dike and the right (north) canyon wall. Willow Beach Wash has also been forced against the left canyon wall. Access Road Wash has not been diked except for very short reaches, but the paved road generally meanders between the left and right canyon walls.

The severity of potential flood and debris hazards in the three washes is mostly dependent on the elevation of facilities and roadways. Another major consideration is the possibility of scour and (or) fill during extreme flood events. Such changes may drastically change the flow carrying capacity of the channels and therefore change flow elevations and velocities in comparison to stable channel-flow conditions. Abrasion and impact forces from manmade debris may be the foremost potential hazard at extreme floodflows. The current flood related hazards in the three washes may be summarized as follows:

A. Willow Beach Wash

As the diked channel capacity is exceeded, spill over the dike may occur along the entire wash or only at vulnerable locations such as constrictions, the outside of channel beds, or places where the dikes are low. Another real possibility is that the diked channel capacity may not be exceeded but erosion from high velocity flow may wash out the dike or retaining wall. The first possibility is considered to pose a greater hazard. In addition, once flow exceeds channel capacity, the movement of manmade debris may compound the flood and natural debris hazards.

B. Jumbo Wash

1. As the diked channel capacity is exceeded, spill over the dike may occur along the entire wash or only at vulnerable locations such as constrictions, the outside of channel bends, and at low-walled dikes.
2. The diked channel capacity may not be exceeded, but erosion from high-velocity flow could wash out the dike or retaining wall.
3. The diked channel capacity may not be exceeded but backwater caused by debris pileup could overtop the dike.

The danger considered most likely is that the diked channel capacity is exceeded. Because manmade debris upstream of the developed area is rather meager and flood durations are short, possibilities 2 and 3 are not considered likely if the dike is kept in good condition. The dike effectively separates the overflow and the main channel; it thus hinders flow from returning to the main channel after the dike has been breached. Hazards associated with manmade debris movement and pileup in the developed area could be severe.

C. Access Road Wash

1. Entrapment and movement of vehicles by extreme floods should be expected.
2. Damages to the Ranger headquarters and employee residences from floods are possible.
3. Road damage caused by erosion and deposition will be a continuing problem resulting from almost all floods.

The above descriptions attempt to point out that the potential flood hazards for a specific wash at a given discharge magnitude are not fixed

but are dependent also on the amount and distribution of available manmade debris as well as the flow capacity of the channel. The delineation and quantification of flood hazards for this study was based on channel-flow capacities as determined by the field surveys of March and April 1977.

Potential Debris Hazards

Intense floods in arid areas commonly mobilize and transport large amounts of debris. The debris, by weight, is mainly composed of rock and inorganic mineral matter. Uprooted and dry dead vegetal detritus are also transported, generally in quantities proportional to the density and character of the vegetation covering the riparian landscape. Man-related debris, although generally a minor-weight component of the total debris load, also commonly comprises an important part of the flood debris loads of developed basins. The organic and man-related components of the total debris load can have pronounced effects on the nature of flooding, because they are generally more buoyant than the inorganic load. This buoyancy promotes congestive jamming and obstructions, and thereby hinders the efficient transport of the floodflows.

Rock-debris also tends to obstruct and modify the floodflows during transit, particularly when large quantities of the debris are bulked into the leading edge of the initial flood wave. Debris at the leading edge of the flow, acts as a moving dam that influences depths of floodwaters behind the front, and the great momentum and abrasive character of the debris movement poses a serious hazard to anything in its path. This moving-dam effect is also capable of diverting the floodpath of the trailing water if the flood channel is poorly incised and the surrounding terrain has a low topographic relief, as is common on many alluvial fans.

Potential debris hazards are related to the quantity and character of debris available for mobilization by the floodflows. Damage can be caused by erosion of valuable land areas, debris deposition, abrasion and impact forces of moving debris, and diversion and modification of floodflows as described above.

Inorganic debris is available in large quantities to be mobilized by floodflows in the major drainages of the Willow Beach area. However, boulders larger than 1 ft diameter are very scarce; thus, the potential hazard for severe impact damage by large-size debris is negligible. All major drainages (Jumbo, Willow Beach, and Access Road Washes) contain abundant quantities of sand, gravel, and cobbles along the major flood courses that will be mobilized during moderate to intense flooding. Some small boulders (less than 1 ft average diameter) are interspersed with fine-size material, but make up a very minor part of the cumulative potential debris load.

The dominantly fine-grained (less than boulder size) composition of the debris in the channels suggests that most debris-related flood damage will consist of erosion, abrasion, and burial. Nonetheless, the badly mangled automobile frames and other structural damage caused by the Eldorado Canyon flood (Glancy and Harmsen, 1975) suggest that abrasion damage can be catastrophic even though large boulder impact is negligible. Likewise, the Eldorado flood experience demonstrated the costly nature of exhuming facilities buried by large quantities of relatively fine-grained debris. Debris deposition will probably pose costly future problems in areas at or near the mouths of principal drainages at Willow Beach.

The quantities of debris movement in the Willow Beach area should relate to peak-flow and runoff volume. These flow magnitudes are related to drainage basin areas (table 1), thus Jumbo Wash has by far the greatest potential to move large amounts of debris. Access Road Wash and Willow Beach Wash have about equal potential for total debris movement, based on drainage area size. The potential debris hazards on the three washes are as follows:

A. Willow Beach Wash

Willow Beach Wash has serious potential problems related to both manmade and inorganic debris movement. The manmade dike designed to confine streamflow to the south canyon wall is likely to be topped by 25-year recurrence interval floods or eroded by smaller floodflows. Sediment eroded will be deposited in downstream parking areas and (or) in the boat marina. The potential for damage to docked boats for 100-year floods and smaller is judged to be minor. If streamflows cut through or overtop the dike, inorganic debris will likely be deposited within the trailer parking areas and also probably around or inside the restaurant-market building, depending on the floodflow depths (fig. 3). The streambed profile of Willow Beach Wash (fig 4), does not show a noticeable flattening near its terminus; this suggests that the lower stream reaches would be efficient pathways for sustaining sediment movement to Lake Mohave. However, in actuality the slopes of the parking and restaurant areas are slightly flatter and would stop some sediment, particularly if floating objects cause partial floodflow damming. The most serious and damaging aspect of debris movement in Willow Beach Wash is that of the mobile homes being swept away from their footings.

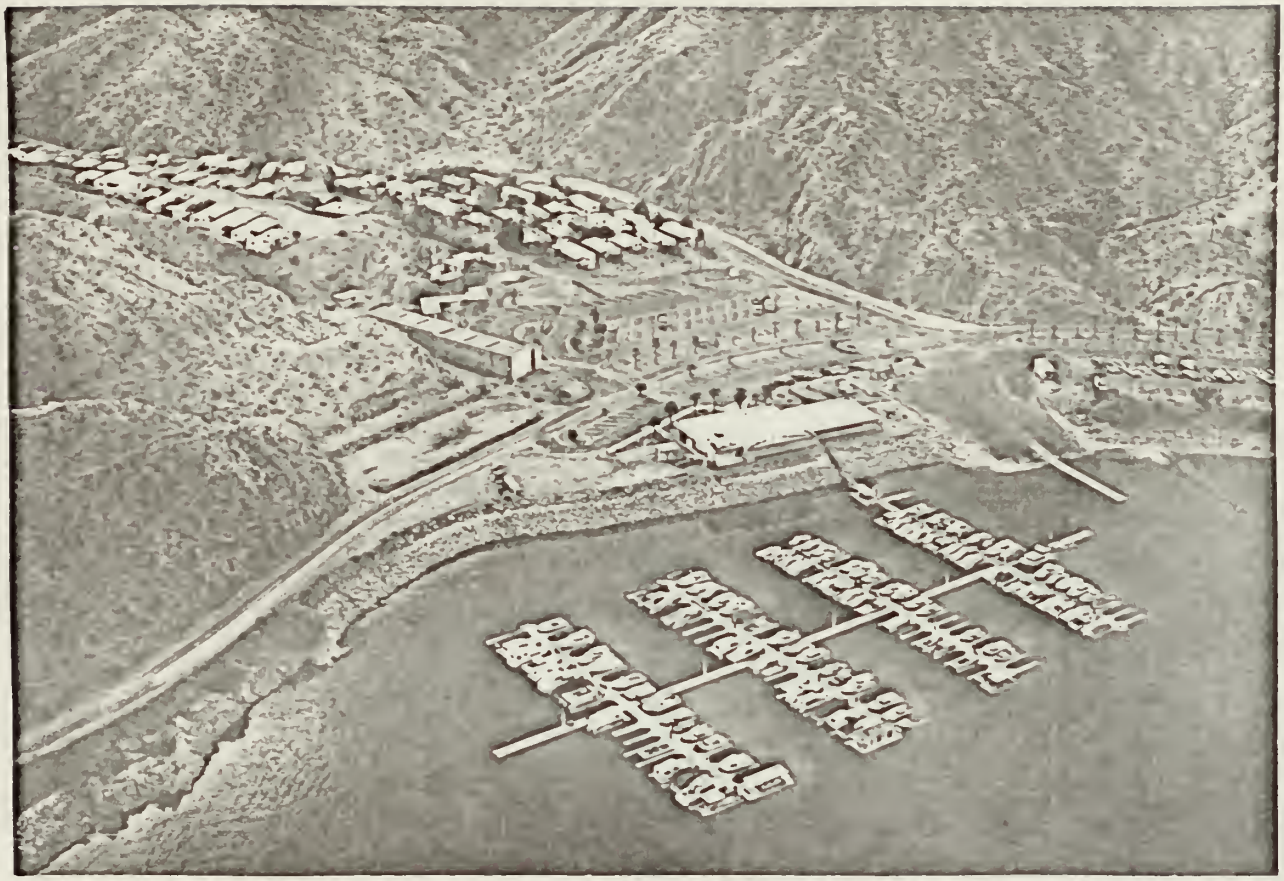

Figure 3.--An oblique view of the mouth of Willow Beach Wash showing manmade facilities, August 3, 1977.

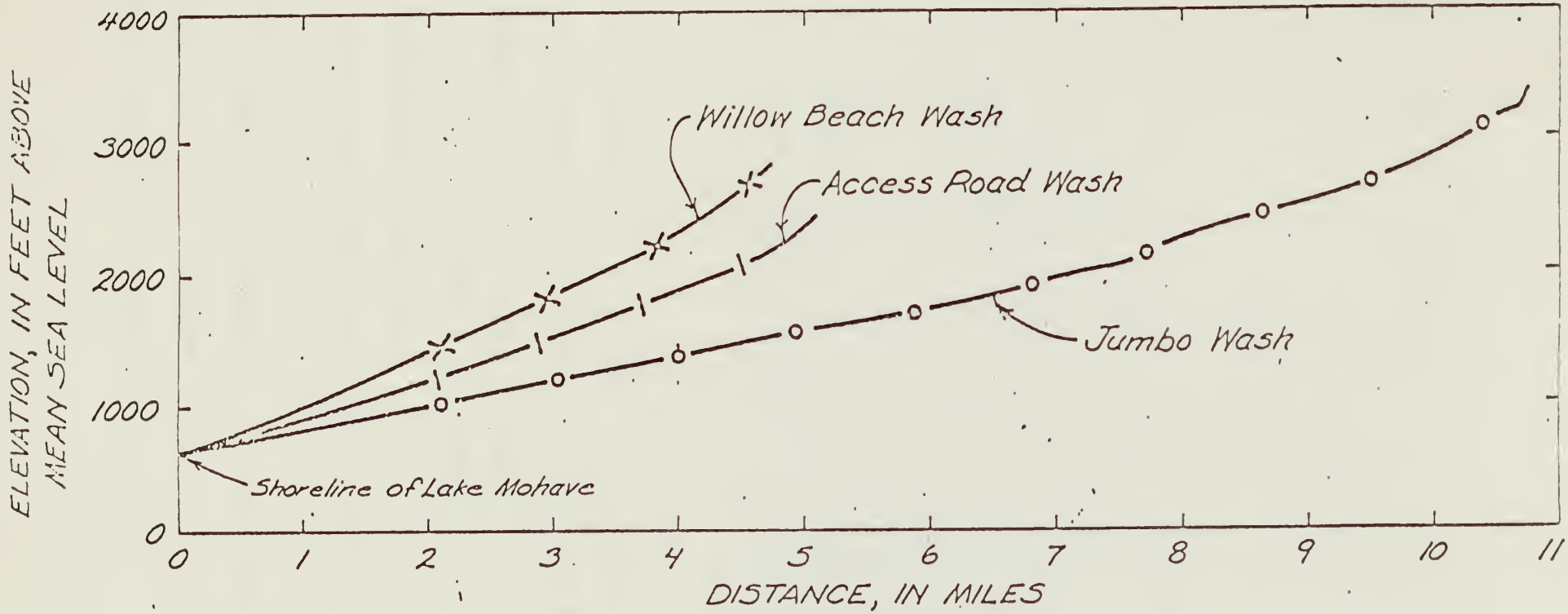

Figure 4.--Streambed profiles of principal washes.

These homes are likely to be moved and severely damaged by the flows and will undoubtedly damage each other by impact during transit. The mobile homes are also subject to impact damage from smaller utility and boat trailers and boats that are now stored in and along the main channel just upstream from the mobile home residential area (fig. 5).

B. Jumbo Wash

Jumbo Wash has potential debris-transport problems, but they are generally less severe than those of Willow Beach Wash. Erosion of dikes protecting campsites and picnic areas are an obvious hazard. Camp areas located near the outside of stream-channel meander bends, such as that shown near the center of figure 6, are most susceptible to erosion. The specific degree of erosion hazard is probably directly related to the magnitude and duration of any given floodflow. If channel erosion breaches the dikes, it will subject the riparian and downstream campsite areas to floodflows, including potential damage by moving debris. Continued erosion beyond the dike perimeter will remove some campsite areas. In the event of intense local precipitation followed by severe overland runoff, the steeply sloping bedrock terrain adjacent to the campsite area (fig. 6) might yield boulders to the main channel of Jumbo Wash. The boulders could subsequently be moved by intense main-channel flows and pose a serious debris-impact hazard downstream.

The permanent picnic facilities and any transient recreationists at the terminus of Jumbo Wash (fig. 7) are subject to impact hazards of moving debris and burial by debris from moderate to large-size floodflows. Sediment deposited recently by floodflows is evident in the sediment-clogged embayment exposed by low lake levels (fig. 7).

Figure 5.--A downstream oblique aerial view of manmade facilities in the terminal reach of Willow Beach Wash, August 3, 1977.

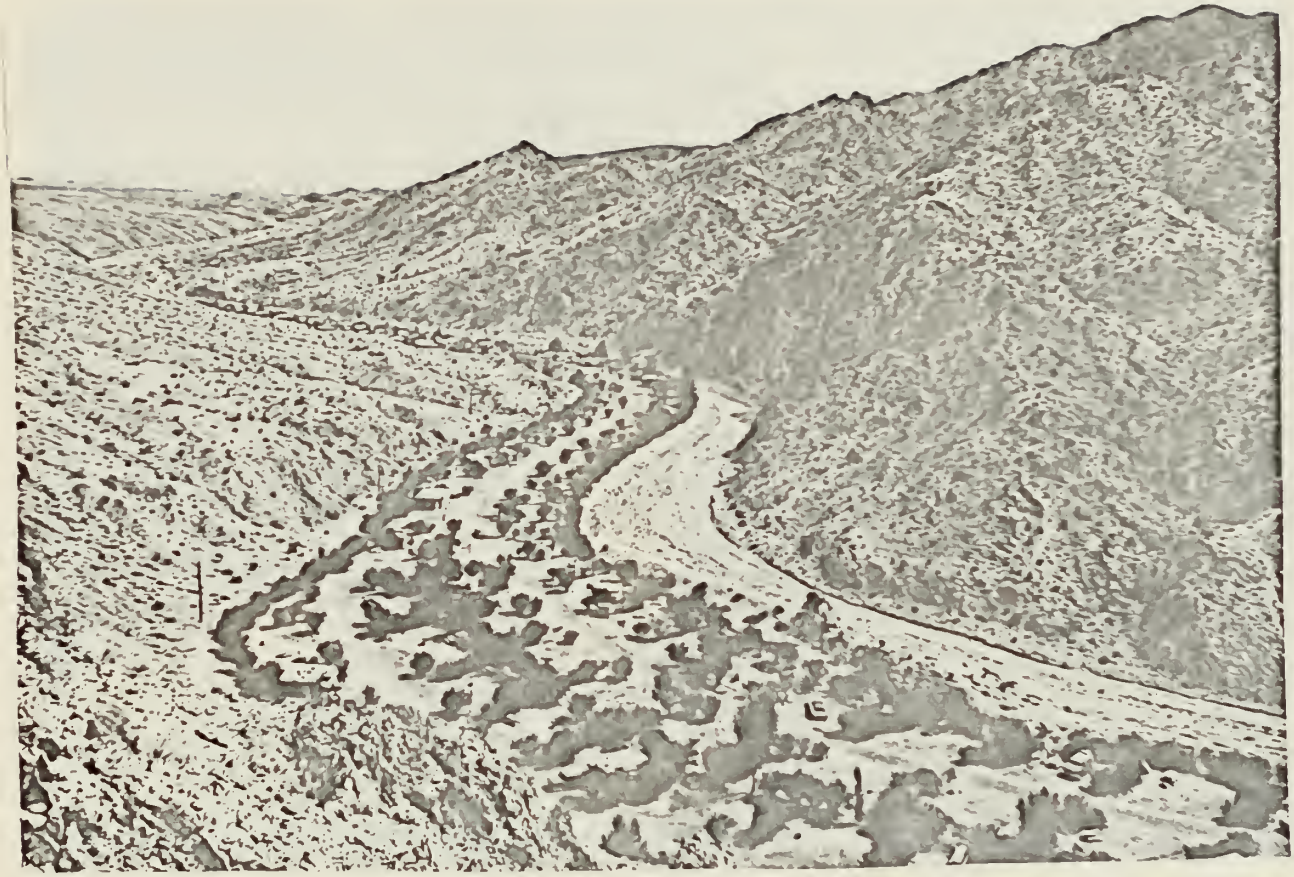

Figure 6.--An upstream view of the channel meander patterns of Jumbo Wash and campsites along the wash, April 12, 1977

Figure 7.--An oblique aerial view of the sediment deposits at the terminus of Jumbo Wash, August 3, 1977

C. Access Road Wash

The smaller number of habitation facilities in Access Road Wash as compared to Willow Beach and Jumbo Washes minimizes the relative overall debris hazards in Access Road Wash. However, the location of the access road poses a threat to people and vehicles moving in or out of the area during flooding periods. The degree of hazard is directly related to the number of travelers in the wash at the time of flooding. In the event of a major flood, travelers could be subject to serious floodflow debris hazards from gravel and small-boulder impact, sediment burial in terminal reaches of the wash, and damage by impact of vehicles being transported by the floodwaters.

The Park Ranger offices and residences are the only permanent buildings located in the path of extreme floods and their entrained debris loads (fig. 8). Damage to these buildings would probably not be too severe except in instances of very large floods. However, the potential hazard is large for storms of a severity comparable to that of the 1974 Eldorado Canyon flood. A storm of that size and intensity could create serious hazards to the dwellings and occupants from debris burial and impact.

Sediment deposition at the mouth of the wash is common and the present state of embayment filling at the terminus of Access Road Wash is shown in figure 8.

Figure 8.--An oblique aerial view of sediment deposits and manmade facilities at the terminus of Access Road Wash, August 3, 1977

DISCUSSION OF STUDY RESULTS

Based on present channel configuration and flow resistance, flood elevations, areas inundated, velocities, and depths were computed for the three principal washes (pls. 1-3). Maximum velocities may be up to 50 percent higher than the mean velocities shown on plates 1-3. Maximum depth is the difference in elevation between the water surface and the lowest ground elevation at the section in question. Pileup due to obstruction and (or) channel curvature (outside curve of bends) may increase depths from those shown on plates 1-3 from about 1 to 2 feet at velocities less than 10 feet per second (fps) to 5 to 10 feet at velocities more than 20 fps. In addition, because the discharges for the different recurrence interval floods have standard errors of estimate of 50 to 100 percent, the shown flow elevations have estimation errors of plus or minus less than 1 foot for the 10-year floods and plus or minus 1 to 2 feet for the 100-year floods. Flow depths and widths of inundation may consequently be over or under estimated.

Conclusions as to potential hazards may be summarized as follows:

1. Willow Beach Wash

For floods of 25 years or greater recurrence interval, the diked channel will probably be overtopped (pl. 1). The approximate limits to the areas inundated for floods of different recurrence intervals are shown on plate 1. The most vulnerable area is from the beginning of the diked reach, section D, to about 600 feet downstream (between sections A and B). Downstream from there, the overflow channel widens appreciably. The precise limits of inundation cannot be determined because manmade debris may cause unpredictable patterns of pileup on the overflow areas.

This wash has serious potential problems from both manmade and natural debris movement. Floods of all sizes pose some debris movement problems. The most serious potential problems are probably those caused by impact damage to dwellings from manmade debris transported by large floods. Sediment deposition in inhabited areas is another serious problem that should be expected from most floods.

2. Jumbo Wash

The campgrounds and facilities on the right bank of Jumbo Wash are in hazardous areas from floods with recurrence intervals of 25 years or greater. In some areas, the dikes provide protection against the 50-and 100-year floods, but at other points in the reach the 25-year flood may top the low-flow bank (pl. 2). The dikes will tend to keep overflow water from returning to the main channel. The precise limits of inundation are difficult to determine because of the uncertainty of the amount and location of manmade debris during extreme flows.

The debris-hazard potential of Jumbo Wash is similar to, but probably less severe than, that of Willow Beach Wash. Manmade debris poses the major hazard through impact damage by moving debris. The campsite and wash-terminus areas are also subject to sediment deposition hazards. The riparian campsite areas will suffer debris problems when the main channel banks are overtopped or if protective dikes are breached by erosions. Wash terminus areas are subject to debris deposition from all floods.

3. Access Road Wash

Because the road follows the wash, most significant flows will top and may damage the road. In addition, automobile passengers may be in danger during extreme floodflows because of the possibility of vehicle

movement by the flows. Based on the analyses, the headquarters and the residences are probably in hazardous areas for flows of 100-year or greater recurrence intervals (pl. 3). This wash probably is the least hazardous of the three washes in terms of overall potential debris hazards. Sediment deposition on the roadway and at the wash terminus should be expected to recur frequently from floods of any magnitude. Magnitude and seriousness of the sediment-deposition hazard will depend largely on the magnitudes of flood runoff.

REFERENCES

Glancy, P. G., and Harmsen, Lynn, 1975, A hydrologic assessment of the September 14, 1974, flood in Eldorado Canyon, Nevada: U.S. Geol. Survey Prof. Paper 930, 28 p.

Matthai, H. F., 1969, Floods of June 1965 in South Platte River Basin, Colorado: U.S. Geol. Survey Water-Supply Paper 1850-B, 64 p.

Waananen, A. O., and Crippen, J. R., 1977, Magnitude and frequency of floods in California: U.S. Geol. Survey Water-Resources Inv. 77-21, 96 p.

EXPLANATION

Approximate flood inundation limits for indicated recurrence interval floods

1.--Flood-flow characteristics at
ected cross sections near the mouth
Willow Beach Wash.


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